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EXPLOITATION OF STEREOPHOTOGRAMMETRICALLY DERIVED 3-D WIREFRAME MODELS TO PRODUCE URBAN SIMULATIONS

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ABSTRACT

The U.S. Army Topographic Engineering Center (TEC) is investigating methods to incorporate photogrammetrically derived 3-D models of urban features into terrain visualization software, to facilitate the photorealistic simulation of urban environments. Ideally, cultural features such as buildings will be extracted automatically from digital imagery as 3-D wireframe models. Coordinates representing the vertices of the models are to be input to terrain visualization software running on a Unix workstation. Phototexture is to be applied to the models and to the underlying digital terrain elevation data in order to create photorealistic, 3-D urban environments for simulated fly-throughs.

DESIRED CAPABILITY

TEC's Terrain Visualization Division (TVD) has already developed visual simulation software that can allow a user to navigate 3-D scenes comprised of image data textured onto terrain elevation values. However, cultural features such as buildings are not represented as true 3-D objects. Apparent variations in elevation are due to terrain only; nothing appears to be above the ground (except artificially inserted models that might be present). Thus, the simulated fly-throughs do not currently benefit from true perspective scenes.

The capability also exists to use vector data files such as the Defense Mapping Agency's Digital Feature Analysis Data (DFAD) and Interim Terrain Data (ITD) products. These vector files can provide location and attribute information

to support the insertion of appropriate 3-D objects into a 3-D scene. However, these vector files are often limited in coverage and in data content.

TEC seeks the capability to fly through digital 3-D databases comprised of not only high resolution imagery draped over true terrain elevation data, but also accurate, geometrically correct 3-D representations of buildings and cultural features that have been extracted from the same imagery. Thus, the area captured on a given image will be fully represented in 3-D. TEC prefers an open systems, commercial off-the-shelf software solution that automatically extracts the information from digital imagery without manual intervention.

CURRENT CAPABILITIES AND ACTIVITIES

TEC has a current contract with a small company that is working on automatic 3-D wireframe modeling of urban surfaces. The system, called WIRE (Wireframe from Imagery using Reconstruction of Elevations) uses an automatic correlation method to produce a dense digital terrain model (DTM) with one elevation value per image pixel. Stereo images are matched (and pixel elevations determined from image parallax) by comparing feature vectors comprised of values computed by mathematical operations performed on intensity values in pixel neighborhoods, not by simply correlating pixel intensities.

The added dimensionality of the feature vector data facilitates the creation of highly accurate DTMs in built-up areas characterized by numerous elevation discontinuities. 3-D wireframe models are created from the 3-D triangular network of the DTM by a process of polygonal relaxation - merging co-planar triangles and smoothing the polygonal edges. Wireframes are to be converted into the ARC projection for visualization on stereo imagery and for perspective scene generation.

The WIRE system is intended to automatically create 3-D

wireframe models that can be used by the TEC's Terrain Information Extraction System (TIES). TEC plans to use these automatic 3-D wireframe modeling techniques for perspective scene generation to support Army mission planning, rehearsal and training for potential conflicts in urban areas.

GEOSET software currently residing on the DSPW component of TIES has a function that allows the creation of 3-D scenes comprised of terrain, features and imagery from a user-specified viewpoint. Given the location and orientation of the viewer, this function can render a scene by draping imagery over both the DTM and cultural features. These features must be extracted manually, however.

This function provides many options. Single scenes can be rendered, or a fly-through can be made consisting of hundreds of scenes. Imagery can be draped over the DTM alone or with features. Features can be textured from the source imagery, or they can be given artificial textures, solid colors, or shading according to a given sun angle. Different features can be textured using different images, according to the user's preference. The viewpoint can follow a simple path tangent to the flight vector, or it can pivot or lock onto designated points. The field of view and the pixel size of the perspective scenes can be varied.

Unfortunately, this function does not allow interactive manipulation of the viewpoint with immediate scene generation. The generation of a perspective scene requires five steps: delineation of the fly-through route, determination of the viewer's look angles along the route, selection of DTM files and feature files that will make up the scene's content, specification of the size and appearance of the rendered scenes, and actual rendering of the output scenes. These scenes are displayed one at a time as they are rendered, and they are saved as individual image files on disk.

TEC has also participated in a relevant Advanced Research

Projects Agency (ARPA) study called "Rapid Construction of Virtual Worlds." This effort sought to address the current state-of-the-art associated with the construction of virtual worlds. It also hoped to identify research and development opportunities having the greatest potential for impacting the processes associated with the construction of virtual worlds.

Some of the areas of opportunity cited in the study were database compilation tools, to include the interfacing of the DSPW with a 3-D GIS, and spatial data representation, which dealt with methods for effective representation of both natural and man-made terrain features.

The discussion of database compilation tools described a scenario involving semi-automated 3-D GIS data collection. The operator of a machine such as the DSPW initiates data collection, e.g., by identifying a prototype feature, and then is assisted by pattern recognition technology to effect the routine extraction of the coordinates constituting that feature.

The discussion of spatial data representation investigated efficient methods of representing terrain as triangular facets, addressing issues such as level of fidelity, integration of cartographic features into a triangular irregular network (TIN), and decreasing the computation time required for TINs. It was recognized that few organizations seem to be researching the difficult problem of built-up area representation. Carnegie-Mellon University (CMU) has been involved in research directed toward automating the extraction and representation of built-up area data from airborne and space imagery. CMU has determined that the use of stereo disparity methods alone will not reliably detect and delineate cultural structures. Therefore, CMU has been investigating symbolic and geometric descriptions of buildings using multiple cues.

PROJECTED ACTIVITIES

TEC will conduct a survey of available methods for extracting 3-D wireframe information from imagery, to ascertain the state of the technology. There is interest in both manual and automatic methods.

TEC will also conduct an experiment in which the WIRE system will attempt to automatically extract cultural features from stereoimagery while TEC researchers manually collect 3-D wireframe information from the same digital data. Both processes will be documented and the results will be compared.

High-resolution stereoimagery of Mogadishu will be used. The images are to be rectified by the TIES system using control points obtained from GPS surveys. These control points are the corners of buildings. A TEC-developed "rigorous rectification" will be performed on each image. The resulting images will mimic aerial frame photography. This will enable them to be used by WIRE 3-D feature extraction software, which requires the input of frame images for subsequent modeling of the relationships between parallax measurements to elevations.

If successful, WIRE will provide the polygonization of an elevation matrix that describes the 3-D locations of urban features such as buildings in the images. Discrete 3-D models will not be provided. Concurrently, 3-D objects from the rectified imagery will be interactively extracted using the TIES system by members of TEC. Data collected by both methods will be used to produce simulated fly-throughs on TEC's platform of choice for visual simulation.

CONCLUSION

Progress made in this area will have tremendous benefits for mission planning, mission rehearsal, simulation and training. The more realistic synthetic environments become, the more effective their use will be. TEC will continue to conduct research in 3-D feature extraction, and welcomes advice and additional information regarding methods,

products and services related to the extraction of 3-D cultural features.

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